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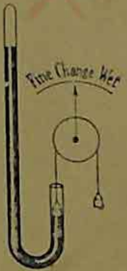

SCIENCE ON THE MARCH
UNIT ONE

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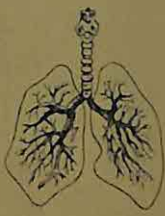

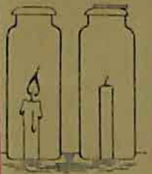

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SCIENCE ON THE MARCH
UNIT ONE

THE AIR AND YOU

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SCIENCE ON THE MARCH
UNIT ONE

THE AIR AND YOU

Introduced by

Science and the Way of the Scientist

John A. Clark
Edith Lillian Smith
Frederick L. Fitzpatrick
Charles H. Dobinson

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The thirteen units of SCIENCE ON THE MARCH:

1 The Air and You.
2 Water and Life.
3 The Weather and the Earth.
4 Life and Food.
5 Health.
6 Energy and Engines.
7 Hearing and Seeing.
8 Electric Currents.
9 Magnets and Electric Power.
10 Earth and Universe.
11 Birth and Growth.
12 Heating and Cooling.
13 Metals and Man (*in preparation*)

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FOREWORD

BY

SIR GRAHAM SAVAGE

GOOD BOOKS can play as important a part in learning science as in other subjects. This part has sometimes been underestimated in the past by teachers who fully realized the importance of providing apparatus and fostering experimental work and accurate observation. Yet books are the chief means by which the accumulated knowledge of mankind is passed on from one individual to another separated in space, and from one generation to another separated in time. It is therefore of the first importance that children at school should form a habit of using books well and of turning and returning to them readily. Those who read at school are more likely to keep alive in after-life their knowledge and interest in science.

We live in an age when, for the first time in the history of man, the achievements of science impinge noticeably on every aspect of daily life and work, from detergents at one end to headline news of jet engines, atomic power and interplanetary travel at the other. It is surely essential that we should try to equip the ordinary citizen before he leaves school with at least a minimum knowledge of general science. It is important that this core of knowledge, which must provide the growing-point for the thoughts and activities of later life, should embrace both the physical and biological fields. But there is no need for any rigid syllabus in a science course, and it is indeed altogether desirable that science courses should differ from school to school according to the differing interests and environment of the children in each. Since SCIENCE ON THE MARCH is published in a series of small books, each providing a UNIT of scientific enquiry, schools can fit them easily into their own differing and flexible syllabuses, in the assurance that the series as a whole does provide a basic course dealing with things and phenomena which are common everywhere.

But the acquisition of knowledge is by no means the sole objective of early science teaching, and it is a great merit of this series that, from the first page to the last, these books strive to get the reader to acquire *the ways and methods of a scientist*. Each book is constructed round a number of problems, and each problem is tackled by several problem-questions. Thus the knowledge imparted by the reading is always in the context that science is not only a body of knowledge but also a method of thought involving experimentation, observation and reflection often leading to more experimentation. The many photographs of simple experiments should help to give the reader a feeling that he or she is taking a small part in this process of finding out—even in those schools where, unhappily, there are difficulties in the way of very much practical work.

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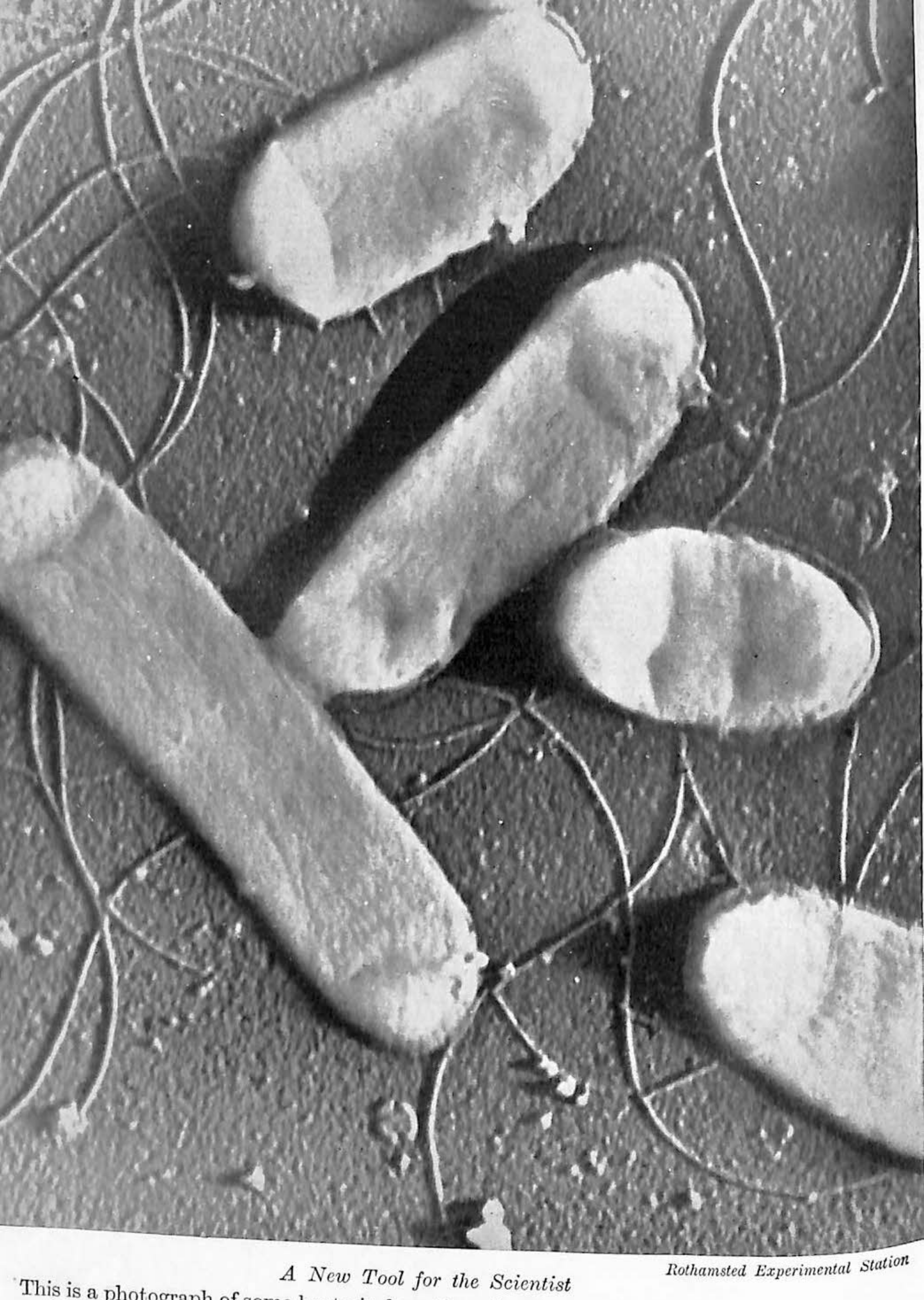


A New Tool for the Scientist

Rothamsted Experimental Station

This is a photograph of some bacteria from the soil. In this photograph the bacteria are nearly 50,000 times their actual size. They are far too small to see in an ordinary microscope but this photograph has been taken through an electron microscope. The slender whip-like threads were part of the bacteria and made them move.

Science and the Way of the Scientist

SOME RECENT SCIENTIFIC DISCOVERIES

Aeroplanes. Have you had your first ride in an aeroplane ? If so, you may have been surprised that it did not feel in any way like being in a motor-car. If the plane was a closed one, you had little or no sense of speed, partly because you could not feel the wind against your face and partly because you were passing over houses and trees rather than going by them. You probably had no awareness of height, and felt very much safer than if you had been standing on the edge of a high cliff.

There are many kinds of modern aeroplanes. They include some that are not much larger than a big motor-car and are very easy to fly. The helicopter is a special kind of small plane. Fighter planes are sometimes small, too, but modern types are jet-propelled and fly at very great speeds. Do you know the latest record ? Then there are the large transport and bombing planes. Some of these are huge ships of the air weighing as much as 50 tons and able to carry either a large group of persons or tons of freight. There are also planes, both large and small, that are built to rise from and alight on the water.

Have you seen pictures of the old planes of only a few years ago ? Compared with what we have today, they must have been slow and awkward. For one thing, they were only partly streamlined, and their landing gear hung down below when they were in flight. Today aeroplanes are carefully streamlined, so that they are not held back by air resistance. Even the landing gear is now drawn up into the body of the plane when it is in flight. Scientists are continually making careful studies of wing length and curvature in order to perfect designs suited to many different purposes.

Air routes cross broad deserts and vast tropical jungles where there are not even cart tracks. Some planes fly at such great heights that oxygen must be supplied to the passengers. Such planes must be heated, for even in the hottest weather they are travelling through air of which the temperature is far below freezing-point. This tremendous development in aeroplanes has been the result of work carried on by a great number of scientists and experimenters during the brief period of fifty years. Do you know the date of the first flight across the English Channel?

Plastics. Parts of some of the newest planes are made of substances called *plastics* that did not exist a few years ago, but which were created as a result of experiments carried on in scientific laboratories.

About a hundred years ago an American scientist was trying to find a substitute for ivory in making billiard balls. He did not find what he wanted, but he did find a way of treating cotton to get celluloid. Thereafter for a number of years men and boys wore celluloid collars. Everything from babies' rattles to brushes and combs was made from this first plastic.

Now we have many different kinds of plastics made from such things as coal, oil, soya beans, wood fibre, cotton and other materials that come from plants. They are being used to make not only parts of aeroplanes, but parts of motor-cars, radio sets, and all sorts of things that we use, including even clothing. It is no longer necessary to get bristles from pigs to make brushes. These can be made from plastics. So can playing cards : they wear much better than those made of paper. More important than such things are the clear glass-like plastics which do not break or shatter and are therefore much safer to use than glass. Can you name five things in your home that are made of plastics ?

Sulpha drugs. Other very recent discoveries have given us some new drugs. Among these the complex substances known as the sulphonamide, or sulpha, group are outstanding. The famous M. & B. drugs belong to this family and gave to man the first effective weapon against pneumonia and a range of other killing diseases. Other drugs of the group are now man's chief defence against various tropical illnesses.

The story goes back to the early days of the twentieth century when an almost unknown chemist found a new substance that had been made from coal tar. At the time, such materials were used largely as dyes, and his discovery seemed to have little importance. Time went on and another man tried the new dye in some laboratory experiments. He was not interested in dyes, however, but in their possible effects upon germs. He gave the substance to mice which had pneumonia and found that some of them recovered.

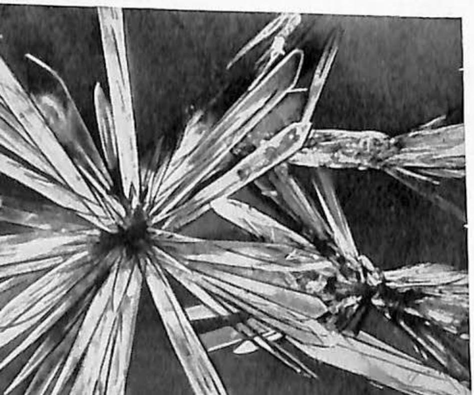
Other scientists were interested, and soon this substance and others that are closely related were being tested in many laboratories in different parts of the world. Surprisingly good results began to come from some of the experiments and doctors everywhere began to use the so-called sulpha drugs. As a result, hundreds of thousands of people, who would have died from pneumonia and many other diseases, are alive and well today. Meanwhile work on the sulpha drugs still goes on in many laboratories and new findings are still continually being reported.

Penicillin. Even more exciting was the work which led to the commercial production of penicillin. Not only was this a race against time to aid the Allied armies in the Second World War, but it shows the way of the scientist at its best. It has been called the greatest scientific " combined operation " ever undertaken for the good of humanity.

In 1929 Alexander Fleming, working in a London hospital laboratory, noticed something strange about one of the experiments in which he was cultivating and studying the germs that cause boils. He saw that where a spore of a mould from the air settled and grew, something was produced which dissolved the germs. He seized on this chance happening and followed it up with superb scientific skill, but he was unable to isolate the substance—penicillin—which the mould produced. H. W. Florey, as leader of a team of workers at Oxford University, later succeeded in obtaining the substance, still impure, in a powdered form. But the team could not find a method of producing penicillin on a large scale. Fortunately, American scientists now joined in. After thousands of experiments they discovered a new strain of the mould which produced more of the drug. Then, after the expenditure of millions of dollars in trying out possible ideas, they found a new method of growing it on a large scale. Now the whole of humanity is helped by a drug which acts almost miraculously in curing blood poisoning and some of the world's most dangerous diseases.

FIGURE 1. Penicillin crystals.

Photo by courtesy of Glaxo Laboratories



In addition, this discovery showed scientists that there is a new and hitherto unexplored world where they might look for drugs—namely, in the substances which microscopic plants produce as they live and multiply. As a result many wonderful new substances, like terramycin, have been found.

HOW OUR KNOWLEDGE OF SCIENCE GROWS

While some one person may get the credit for an invention or discovery, you must remember that he has made use of many facts discovered by others. This was true of the story of penicillin, which also shows how modern advances often depend upon teams of workers, whose names are never known to the general public. Yet many of these unknown scientists may have played important parts in that chain of advances which made the final achievement possible. Today there is a world organization which helps scientists of many nations to keep contact with one another.

Penicillin and the sulpha drugs tell us stories of the growth of scientific knowledge in the healing of disease. The story of vitamins tells us of the growth of scientific knowledge in the maintenance of health.

Vitamins. Long before anyone even dreamed of such things as vitamins, it was known that eating some rather strange things helped to keep people well. One of these things was the juice of a small fruit, quite like a lemon, called a *lime.* Another one was an oil taken from the livers of codfish.

Over three hundred years ago it was found that many sailors became sick on long voyages. They had aches and pains and often severe nosebleeding. Many died from this disease, which they called *scurvy.* No one knew the cause, but it was found that sailors who drank lime juice did not get scurvy. So lime juice became a regular part of the food of English sailors.

Culver Service

FIGURE 2. This old advertisement for cod-liver oil was well known long before vitamins were discovered.

Later it was discovered that for some reason babies and young children grew better and had stronger bones and better teeth if they were given cod-liver oil. No one knew why; it was just a fact.

The Japanese sailors, as well as many of the people in the Far East, also suffered from a serious disease which they called *beriberi*. These sailors lived chiefly on polished rice. This is rice from which the outer husks have been removed. When the Japanese heard about the lime-juice cure which the English had used, they began to give their sailors other foods in addition to rice. After several trials with different kinds of food they got good results, but still no one really knew why the sailors kept well.

Up to this time no experiments had been tried to find the real cause of the disease. One scientist, however, noticed that chickens fed on polished rice also died from a disease much like that of the sailors. So he began to do some experiments with chickens. He found that if the sick chickens kept on eating polished rice, they died. But if they were given, along with their polished rice, some of the husks that had been removed from the rice, they got well. Then he tried giving rice husks to people who had beriberi, and they too recovered. From this he felt sure that *something* in the husks of rice grains prevented beriberi.

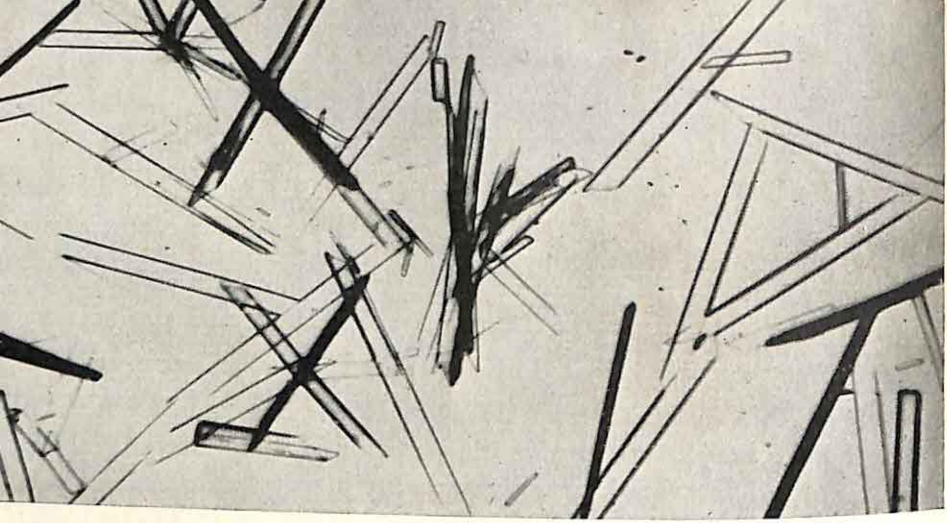
Although a good start had been made in the study of foods and health, it was not until 1911 that another scientist was able to get the helpful substance from the rice grains. He did not know what the substance was, but gave it a name, *vitamin*, meaning " life-giver."

Other scientists found that rats fed on a mixture of certain pure foods, such as sugar, starches, fats, and so on, became sick and died. But if only a *few drops* of milk were added to the diet, the rats got well. From this they felt sure of two things: (1) milk contains *something* needed in a good diet, and (2) the amount required for good health must be very small.

After these discoveries thousands of experiments were made to test common kinds of food for vitamins. As new ones were discovered each was named by being given a letter. The vitamin in rice husks is now known as *Vitamin* B_1. The one in lime juice that prevents scurvy is called *Vitamin C*; the one in cod-liver oil that prevents rickets is *Vitamin D*, and so on for several others. You probably have seen long lists of foods and their vitamins in magazines and books.

Now came what may prove to be the most important step in this growth of knowledge about vitamins. People were now asking the question: " What is a vitamin anyway? Is it like starch, or sugar, or salt, or what?"

Of course this was a question for chemists. While any of them could tell you that water, for example, is H_2O (two parts of hydrogen and one of oxygen), not one of them knew the make-up of a vitamin. It took " a shipload of rice polishings and a lake full of water " to prepare a very small quantity of Vitamin B_1 for experiments. Of course it was far too expensive for common use. But after testing tons of foodstuffs, and after years of hard work, chemists at last found the make-up of some vitamins. Then chemists were able



Merck & Co., Inc.

FIGURE 3. How vitamin B_1 looks under a microscope.

to *make* them instead of taking them from foods at great expense. Because they succeeded, we can now buy various vitamins cheaply and in convenient forms.

Many other discoveries and inventions have changed our world. Compare the old stage-coach with present-day trains, motor-cars and aeroplanes. Or compare the little wooden sailing ships of Drake with the *Queen Elizabeth* or *United States*, and other liners of today. Likewise, great changes have taken place in our towns, which are altogether cleaner and healthier than a hundred years ago, and in our homes and in the things we do. Dentists, plumbers, firemen, bakers, milkmen, motor-car mechanics, aeroplane pilots, cinema operators, builders, navvies and miners all have had their work made more efficient—or even made possible —by the scientists.

All this has given mankind greater opportunities.

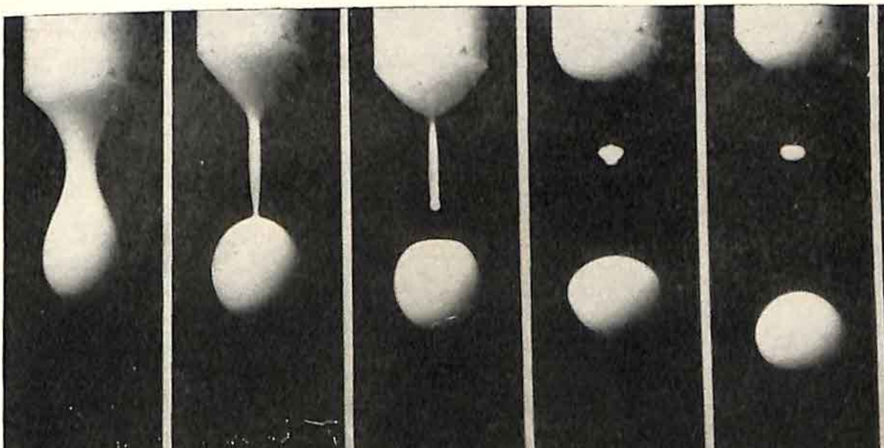
Reading. You have just read about some of the work done by scientists. Such reading is one step in learning to work as a scientist, but there are many others. In addition to reading, for example, it is often necessary to make a careful study of pictures.

Studying pictures. You can now see pictures of all sorts of things which have come from the work of scientists. Careful study of the pictures will lead you to a better understanding than you would get from words alone. Sometimes you may watch slow-motion films, and see exactly what happens when the motion is so fast that your eyes cannot follow it. For instance, you can tell at a glance that the falling drop of milk in Figure 4 is not a sphere.

Observing. Information about plants and animals comes chiefly from your own observation and that of other people who have studied them directly, both outdoors and in the laboratory. So, too, you learn about the non-living things of our world through your own observations or those of others. Whether or not you get the real truth depends upon how carefully the observations have been made, and also on how honestly

FIGURE 4. How does the shape of the drop of milk change as it falls?

Photograph by Edgerton, M. I. T.



and accurately they have been reported. You must be careful that you do not report as an observed fact something that you merely expected to see. The idea you get may be entirely wrong if your observation was careless in the first place. And there is always danger that the evidence that you have observed is incomplete, or that it is not the right kind of evidence to use in drawing the conclusion that you are trying to reach.

Using a microscope. The microscope is our most important aid in observing very small things. Through its use in studying germs men have made discoveries which have done much to keep us well. Microscopes are also in almost constant use in factories. You yourself will need to use a microscope in your study of science; if you can't, the next best thing will be to study photographs taken through one.

Using a telescope. The telescope is an instrument used to observe far-distant objects. It has enabled scientists to learn about the moon, the planets and the stars. When you look at things through either a telescope or a microscope, you are making observations. Like any others you must make them carefully if you want to get the facts.

Using a camera. Cameras are used in many kinds of scientific work. They give a permanent record of things that have been observed. Thus pictures, including motion pictures, can be of great value, but again we have to be careful. A picture can sometimes be very misleading. The sizes of different objects, for example, may depend upon where the camera was held when the picture was taken. It is possible to take a picture of a fly so that it will look as large as a horse!

Experimenting. Probably scientists have learned more by observing the results of experiments than in any other way. Some experiments are very simple, such as testing oranges to find out whether they are heavier or lighter than water. Are you *sure* you know? Others are very difficult, such as finding a way to make a rubber thread from alcohol. But whether your experiment is simple or difficult, when you have once completed it correctly, you no longer have to guess at the answer. The results speak for themselves.

Sonotone Company

FIGURE 5. Experimenting to get facts about deafness and aids for hearing. The girl in the picture will drop her finger when the sound becomes too faint to hear.

Of course, if new facts are found by other experiments, you must change your conclusion to make it agree with all the facts that are known. You might find, for instance, that every orange you tested would float, and conclude that oranges are lighter than water. But someone else might later find a kind of orange that would sink. You would then have to change your conclusion and say that some of the oranges float and others do not.

Scientists constantly experiment and compare their results with the findings of others. In this way they get nearer and nearer to the whole truth about such matters as the causes of diseases, the way plants grow, how we see and hear, and what electricity really is.

Because the great changes in our way of living are due chiefly to the work of scientists and to those who think and act like them, it will be interesting to know what a scientist believes.

A scientist believes that it is his business to find the truth without minding whether people make fun of him or praise him.

A scientist believes that to find the truth he must get all the facts he can. Thus he pays little attention to the ideas of anyone who has no facts to support them.

A scientist has learned to believe that when things happen there is a cause. Hence he thinks the number 13 is just like any other number, neither " lucky " nor " unlucky," and that such things as black cats and lucky charms have no effect upon life.

A scientist believes in changing his mind if new facts are discovered which shed new light on a problem.

A scientist respects the ideas of others even though he may not agree with them, and he is not ashamed to say " I don't know."

If you tell a scientist something, he is likely to say to himself "I wonder", or if you ask him a question he is likely to say " Let's see." This is because he thinks it unwise to make a positive statement until he has thought about the matter from all sides.

One of a scientist's strongest beliefs is that experiments are the surest ways to get the facts and to test ideas.

Science clubs. Many people now train themselves to think like scientists. You will be thinking and experimenting like a scientist in some of your daily work. To help young people to get more practice in the scientific method of doing things and in learning some of the hows and whys of science, many schools have one or more science clubs.

Perhaps your school already has a Camera Club, or a Chemistry Club, or a Geology Club which you may join. You may enjoy belonging to a Biology Club, where you do such things as study the life of bees in a glass window-sill hive, or grow plants without soil.

The work you do in a club is not only a help to you in your learning, but as one boy said, " It's fun : and I like to work with other people." If there is no club you care to join, why not ask if you may form one ?

WHY YOU STUDY SO MANY DIFFERENT TOPICS

As you read this book you may wonder why you have to study so many different kinds of topics. The reason is not hard to see.

Suppose a girl is helping her mother to prepare a meal of roast lamb and mint sauce, green peas and new potatoes, followed by gooseberry tart and custard. If she wants to know why such a combination is good for health as well as for appetite, she must study what each of the foods contains. But she also ought to learn how long to cook each kind of food so that all will be ready at the same time. She will also want to know how to set the table and make it look attractive. There may seem to be little connection between cooking potatoes and making a pretty arrangement of flowers, but both are necessary parts of a really successful dinner.

Or consider a boy who wants to do really well at football. Of course he must know about the markings on the field and the size and position of the goal posts. But he must know many other things, such as the correct motion of the leg in kicking, the best foot movements in passing and the best position of the arms when

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falling so as to avoid injury. Off-side rules and ways of falling are entirely different topics, but knowledge of each of them and of all the others is necessary if the boy is to play the game well.

So it is with Science. If you are to learn the laws of Nature, which a great scientist once called " the rules of the game of life," you need to study several topics. Then you may discover how science can assist you to look after your health and that of others, how it will make life more interesting wherever you may be, and how it will help you to become wiser and more understanding. And some of you may find science so absorbing that you will wish to earn your living in one of the many branches of scientific work.

SOME THINGS YOU MAY CARE TO DO

1. In some parts of the United States, English sailors are called " limeys." After one American boy had read about the use of lime juice by English sailors he said: " Now I see how they got the name ' limeys.' " When told that the name had nothing to do with lime juice, but probably came from the word " Limehouse," the name of a part of London where there are many docks, he seemed surprised.

What did the pupil do that a real scientist would not have done, and thus come to a false conclusion ?

2. The pupil might well have said: " I wonder if that's the reason why English sailors are sometimes called ' limeys ' ? "

Give at least two reasons why this remark would have been much better than the one he first made.

3. Give a reason why a scientist does not think it is unlucky to do such things as walk under a ladder, or stand under an open umbrella inside a house.

4. For years many persons thought it was better not to take water with their meals. They thought it would keep food from digesting quickly. When scientists finally tested this idea by experimentation, they found, to the surprise even of doctors, that water helped digestion rather than prevented it. So today people generally drink all the water they wish.

What two statements of the beliefs of scientists (page 20) does this account illustrate ?

5. From what you have read in this book, give an example of how science has helped (*a*) to relieve suffering, (*b*) to improve health, (*c*) to improve travel, (*d*) to help break down the barriers between nations.

6. Find out what you can about the work of the World Health Organization.

ACCURATE READING

Scientists try to collect all the information they can about questions they want to answer. They try to set this down as accurately as possible, but we as scientists must learn to read accurately.

Read the story of the discovery of vitamins. To see how much you learned from your reading, answer the following questions.

1. Was scurvy avoided on English sailing vessels by giving the sailors (*a*) cod-liver oil, (*b*) lime juice, or (*c*) polished rice ?
2. Were vitamins discovered by (*a*) Edison and Bell working together, (*b*) Japanese sailors, or (*c*) scientists of different nationalities ?
3. Is (*a*) beriberi, (*b*) rickets, or (*c*) scurvy a disease more often found in the Far East than in Europe and America ?
4. Under a microscope, are vitamins seen (*a*) as squirming, round animals, (*b*) as needle-like crystals, or (*c*) not at all ?
5. Do the foods that prevent scurvy contain (*a*) vitamin A, (*b*) vitamin B, or (*c*) vitamin C ?
6. Is the important vitamin in cod-liver oil (*a*) vitamin B_1, (*b*) vitamin C, or (*c*) vitamin D ?

Air and You

Air is one of the commonest things in the world. Wherever you go on land or at sea you are always surrounded by air. Without it you and all living things would die. You breathe it day and night. You feel it when wind blows in your face. Winds are used to fly kites and to sail boats and gliders. Winds also bring the clouds that give us rain. Wind is air in motion. In this Unit you will think in the way of a scientist about this common thing, and will discover some of the ways in which air is used.

While it is plain that cycle and motor tyres need air, there are many things around you which *seem* to have nothing to do with air, but which do need it. Look at these photographs.

Do you know why

the ink does not run out of the filler ?

the rubber disc does not fall ?

the glider can soar up to the clouds without an engine ?

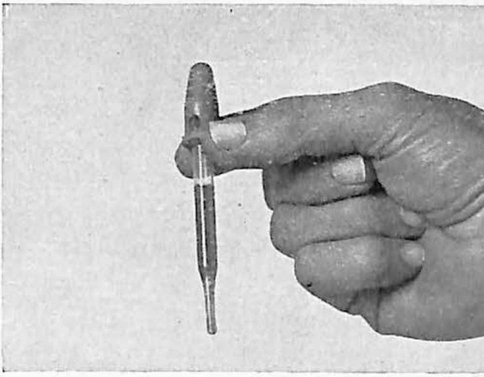
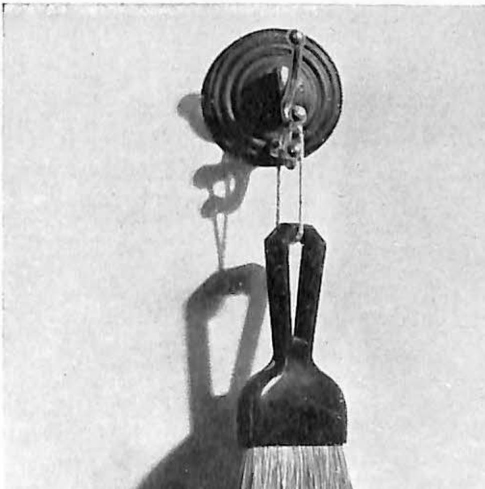
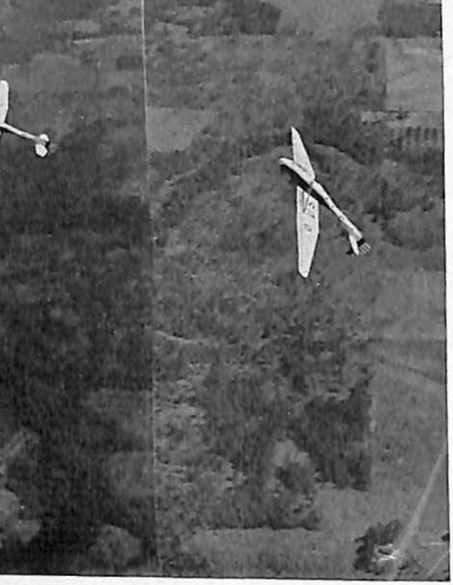


Figure 6. The ink does not flow from the tube.

Figure 7. The disc is not fastened to the glass by anything.



Photographs opposite : 'Illustrated,' Mirrorpic, Crown Copyright Reserved and Keystone Press Agency Ltd.



Acme

FIGURE 8. There is neither engine nor propeller in this glider.

To help you to answer these questions about the pictures, and to understand how air causes some strange things to happen, you will need to find out first of all whether or not air is a real substance. Nearly always an experiment will help to give you the answers to such questions.

Problem A: IS AIR A REAL SUBSTANCE ?

You probably have an opinion on this question, but are you sure it is correct ? Even though you can feel air, can you be sure that it is as real as water ? Remember that you can feel sunshine, which is not a substance. To make sure about air, you will need to do some experiments to find out whether it takes up room and has weight. If you can find the correct answers to the three problem-questions that follow, you will be able to come to a scientific conclusion as to whether or not air is a real substance. You will then be better able to understand some of its uses.

Problem A: Is Air a Real Substance ?

Question 1. Is an Empty Bottle Really Empty ?

You can, of course, pour water through a funnel into an empty bottle, but can you do so if the funnel fits the neck of the bottle tightly ? You can find out by the following experiment. You can make a tight fit if you

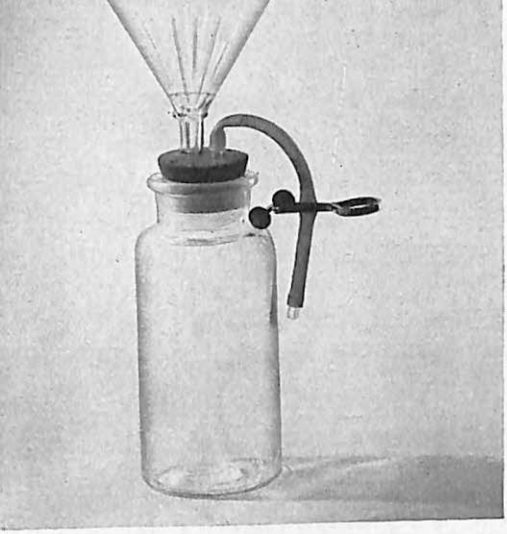


FIGURE 9. A cork stopper should be coated with paraffin wax to prevent leakage.

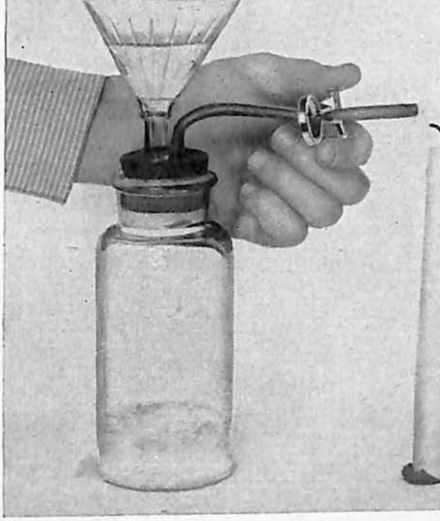


FIGURE 10. The clip is just being opened.

pass the stem of the funnel through one hole in a two-hole rubber stopper which is placed in the neck of the bottle. In the other hole place a piece of glass tubing, to which is attached a short piece of rubber tube with a clip. The arrangement is shown in Figure 9.

First make sure that the clip completely closes the rubber tube. Do this by blowing into the tube. Then pour water into the funnel. You will probably find that the funnel fills up and that little or no water flows into the bottle. If the funnel does not fill and remain full, hunt for a leak in the apparatus.

Now place a lighted candle, as in Figure 10, so that its flame is about one half-inch from the end of the rubber tube. While the flame is steady, open the clip. Observe what happens to the flame and to the water in the funnel. Clip the tube and repeat the experiment.

What does the action of the flame seem to show?

What happens to the stream of water as soon as the tube is clipped?

Further evidence that something is coming out of the bottle can be obtained by using a glass tube and a jar of water in place of the candle. The apparatus for this purpose is shown in Figure 11. Better results are obtained if the clip is held open only a few seconds at a time.

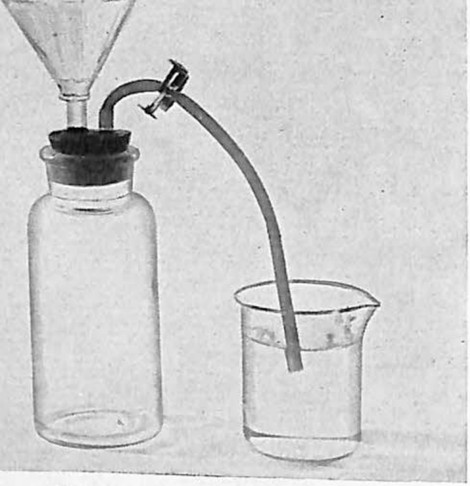


FIGURE 11. Nothing may occur if the end of the tube is too far below the surface of the water. Why?

What is your problem-question?

What is your answer to it?

Does air take up room?

OTHER PROOFS THAT AIR TAKES UP ROOM

Men allow for the fact that air takes up room. If you examine the large funnels used for filling jugs and barrels, you will see that men know that if they wish to pour liquids into them quickly, they must provide plenty of room for the air to escape. Thus you may find the stems of such funnels made with grooves through which air can pass. Moreover, you probably have noticed that the nozzle of the hose used to fill the petrol tank of a motor-car is much smaller than the opening in the tank.

Just as air must move out of a bottle if water is to enter, so air must be moved out of the way when you come into a room, or when a motor-car moves along a road. In your own case only a small amount of air need be moved and you do not notice it, but a motor-car may use several gallons of petrol in a day's run just to push the air aside.

SOME THINGS YOU MAY CARE TO DO

1. Using the apparatus of Figure 9, see if fine dry sand can be poured through the funnel when the clip closes the rubber tube. If it does flow, why would you not change your conclusion that air takes up room ?

2. By using some other method, see if you can force the air out of the bottle fast enough to blow out the candle. *Hint :* If you have no good idea of your own, you might try using water from a tap. Have you thought of placing the funnel high above the bottle by using a rubber tube ?

These experiments are, to be sure, quite easy to do, but they will be interesting and will improve your skill in this work. They will also prepare you for more difficult experiments that you may decide to try later.

Problem A: Is Air a Real Substance ?

Question 2. **Does Air have Weight ?**

You have proved that air takes up room, and thus appears to be a real substance. If it is real, it should also have weight. To settle the matter, it is only necessary to balance a blown-up balloon on one end of a long ruler, and then see if it is still in balance after the air has been squeezed out of it. Figure 12 shows how to balance the balloon. Of course the air outlet can be closed by a rubber band, but a clip is much more convenient, and you are less likely to disturb the apparatus while removing the air from the balloon. It is a good idea to make a notch at the centre of the ruler to prevent its slipping over its support.

Did the empty balloon balance the weight ?

Was the inflated balloon heavier or lighter than the empty one ?

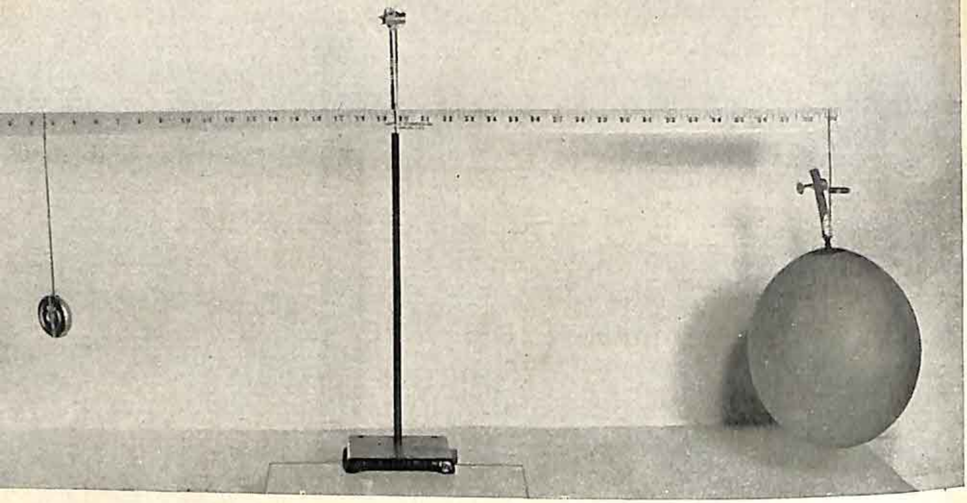


FIGURE 12. Why is the thread which supports the balloon tied *loosely* about the air tube ?

FURTHER EVIDENCE THAT AIR HAS WEIGHT

You may think that the balance was disturbed by the difference in the shape of the balloon. But study the pictures shown in Figures 13 and 14. Here the flask did not change its shape. In this experiment the air was removed by a pump not shown in the photograph.

By placing small weights in the left-hand pan until balance is restored, the weight of air removed can be found. Thus, if a quart of air were removed, the weight of a quart of air would be known. Careful experiments show that a cubic foot of air weighs about $1\frac{1}{4}$ ounces.

Does the air in your classroom weigh about 6 pounds, 60 pounds, or 600 pounds ?

Winds, good and bad. The *weight* of the air may be either harmful or helpful. You know that a heavy substance, like water, can hit a rather hard blow if it is moving as rapidly as it is when it comes from a hose. Of course air is not so heavy as water, but still a barrel of it can hit about as hard a blow as a pint of water if both are moving at nearly the same speed.

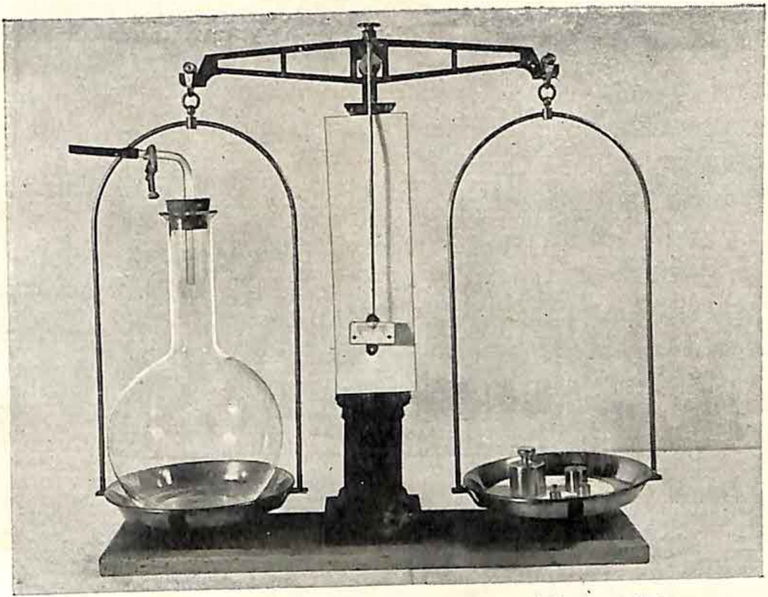


FIGURE 13. A flask full of air balanced by weights.

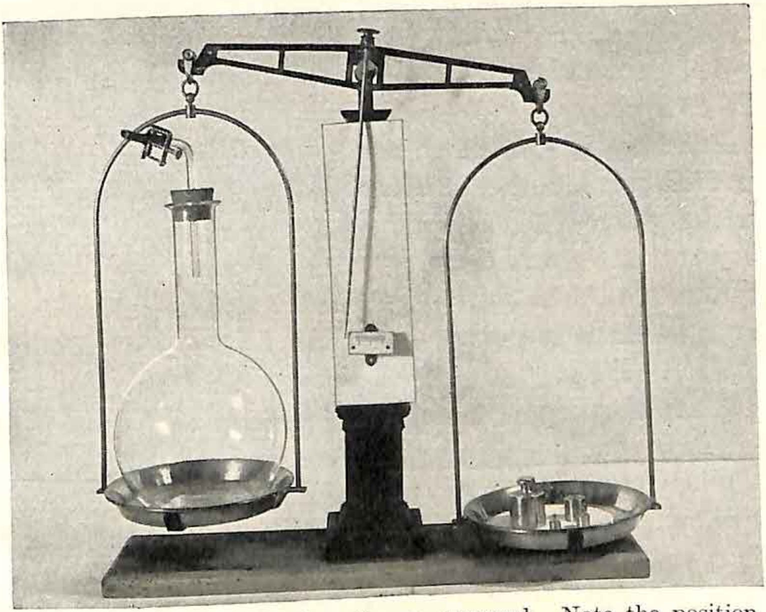


FIGURE 14. The flask after air was removed. Note the position of the beam and pointer of the balance.

We often have winds of from 30 to 70 miles an hour. At 30 miles an hour the air is moving as fast as a car is allowed to go in a town in Britain. You need no proof that winds of high speed strike with great force upon objects in their path. They may do immense damage to trees, ships, crops, and buildings.

Winds that do not push too hard are welcome. Even the rather common wind of 20 miles an hour can exert a push of nearly 15 pounds on a square yard of cloth in a sail. As you go on with your study of air, you will see how important the weight of the air really is.

SOMETHING YOU MAY CARE TO DO

See if you can show that hot air weighs less than cool air. You will need a large can holding not less than a gallon. If it is one that has been used for motor oil, rinse it out with a little paraffin, and then wash it with soap and water. Make sure that it is dry before using it. You will also need a razor blade, two large corks, some small blocks of wood, a long ruler and the lid of a tin.

Balance the can as shown in Figure 15 by placing just the correct amount of sand or other heavy material in the pan. Then slip blocks under the pan so that it just rests upon them.

Remove the stopper and heat the can very hot with a gas flame or in the oven, so that the can is filled with hot air. Be careful not to get any soot on the can. Replace the stopper loosely, and as soon as the apparatus is perfectly still, carefully remove the blocks.

Because the hot metal of the can weighs the same as it did when it was cool, any change in the balance must be caused by a change in the weight of the *air* in the can. Is balance regained when the can becomes as cool as the air ?

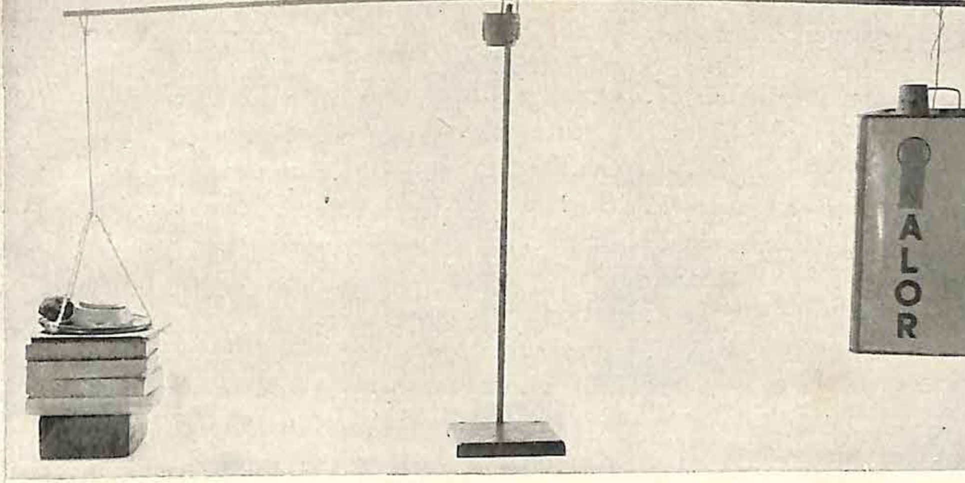


FIGURE 15.

Problem A: **Is Air a Real Substance?**

Question 3. **Does Still Air Push against Objects?**

You have seen that moving air exerts a force upon objects. You know, too, that any object you may be carrying on your shoulder presses against it even when at rest. Thus, it is reasonable to suppose that air piled high above the earth might also push upon everything below it. If any such push does exist, however, you cannot feel it, nor does it break or even bend such a delicate thing as a soap bubble or a thin sheet of paper.

Many experiments have been made to test this question. One of the best is to fasten a thin sheet of rubber over the end of a glass funnel, as shown in Figure 16. This arrangement gives you a flat piece of rubber with air on both sides of it.

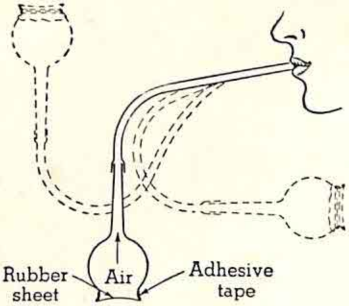


FIGURE 16. Why should the tongue be placed over the end of the tube while the funnel is being held in the different positions?

You know that air can be drawn into the mouth by sucking it in. If you suck on the tube, you can take some of the air from the funnel. Since you did not pull upon the rubber, but merely took some of the air out, *what do you think pushed the rubber into the funnel?*

The force of the air upon a square inch of an object is called *air pressure*, or *atmospheric pressure*. By moving the funnel as shown by the broken lines in the figure, you can find whether the air exerts a pressure sideways as well as downward. *In what direction or directions does the air push? Is it greater in one direction than in another?*

AIR PRESSURE

Why air pressure is great. Because each cubic foot of air weighs about $1\frac{1}{4}$ ounces, and because the lowest cubic foot has to bear the weight of all the air directly above it, you can see that if the air were only 200 feet high, the force would be $1\frac{1}{4}$ oz. $\times 200 = 250$ ounces, or about 15 pounds on a square foot.

The air is, however, much more than 200 feet high; it is miles high in fact. Later in your science work you can prove that the pressure is about a ton on a square foot, or about *15 pounds per square inch.* About how great is the force against one side of a pane of glass in your window? Why does it not break the glass?

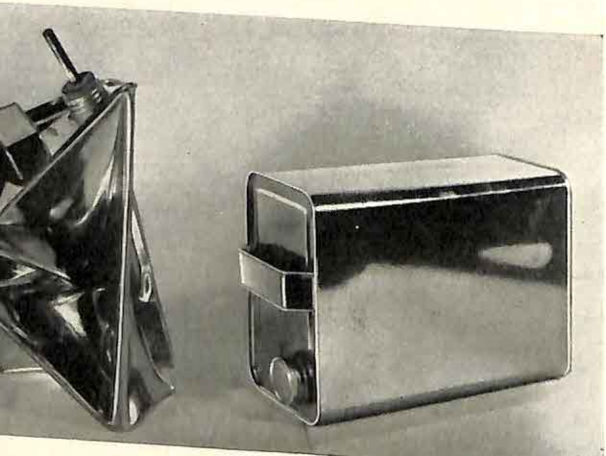


FIGURE 17. When the air was removed from the can on the right, the air pressure crumpled it as you would crush a paper bag.

Figure 17 shows that air pressure is great. In this case the air was removed from the can by means of a pump not shown in the picture.

Air pressure and the aeroplane. One of the most important uses of air pressure is to lift aeroplanes. When a plane is resting on the airfield the pressure of the air upon both the upper and the lower surfaces of the wings is the usual fifteen pounds per square inch. But when it is made to move along the field, the wings have to fight their way through the air. As they do so, the air which strikes the lower side of the wings pushes against them, but this force is not nearly enough to lift the plane. The air that rushes *over* the wings, however, does not strike them, but sweeps by them in such a way as to reduce the air pressure upon their upper surfaces.

The pressure upon the upper surfaces is thus less than the usual fifteen pounds per square inch. Suppose it is only fourteen pounds per square inch. This is, of course, one pound less than the usual air pressure on the lower surfaces. The lift due to this difference is then 144 pounds per square foot. This is in addition to the force of the air striking against the lower surfaces of the wings. With well-made wings the lift due to the difference of pressures is about twice as great as the lift due to air striking against the under surfaces. Perhaps you have seen pictures of aeroplanes which weigh over a hundred tons when loaded. Do you now see the reason for such large wings ?

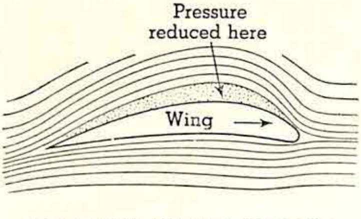


FIGURE 18. The pressure above the moving wing is less than that under it.

You have seen that air takes up room, has weight, exerts a force when in motion upon objects in its path, exerts pressure when at rest, and that air pressure helps to lift aeroplanes. What now is your answer to the question: *Is air a real and useful substance?*

Can you now see why the ink in the filler shown in Figure 6 cannot force its way out?

How is part of the air removed from under the rubber disc in Figure 7 so that the pressure of the air on the outside can force it against the glass?

SOMETHING YOU MAY CARE TO DO

Crush a stoppered tin, such as a paraffin can, by means of air pressure. A pump is not needed, because the air may be forced out of the can by boiling about four tablespoonfuls of water in it. The water should be boiled vigorously. While steam is coming from the can, remove it from the heat and quickly insert a tightly fitting stopper.

As the can cools, the steam in it will begin to change back to water and thus reduce the pressure inside the can. If the stopper fits tightly, the can will probably begin to give off a snapping sound and then suddenly collapse when it can no longer withstand the air pressure. How could you cool the can more quickly?

Problem B: **HOW IS AIR RELATED TO FIRE?**

You have seen how the weight of the air causes it to push upon objects, and you have learned how this force is sometimes used. But there are other uses of air which are not due to its weight. One of the most important of these has to do with fires. In studying this subject you will learn that air is a mixture of various gases.

Everyone has seen substances burning in the air, and knows that fires burn better when there is a draught or a wind. These facts show that air has something to do with fires, and bring up some questions which will help you to solve the problem.

Problem B: How is Air related to Fire?

Question 1. **Will a Fire Burn without Air?**

An easy way to find whether fire will burn without air is to start a fire in air and then cut off the air supply. To do this, light the wick of a short piece of candle and then cover it with a tumbler as shown at the bottom of Figure 19. *Does the candle continue to burn?*

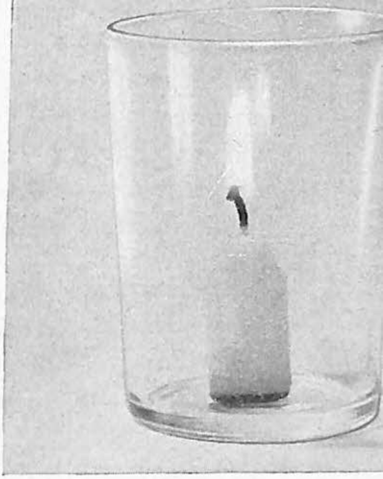
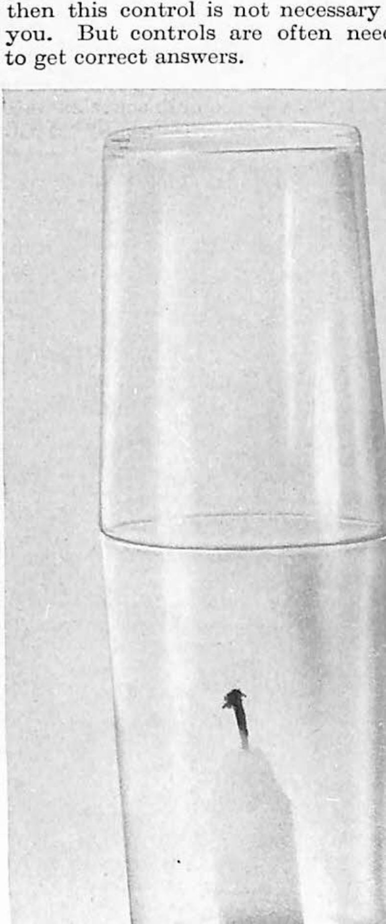


FIGURE 19. The candle burning in
tumbler above is called a *control*. I
used to show that a candle will bur
a tumbler which is open to the air.
you know from experience that it
then this control is not necessary
you. But controls are often nee
to get correct answers.

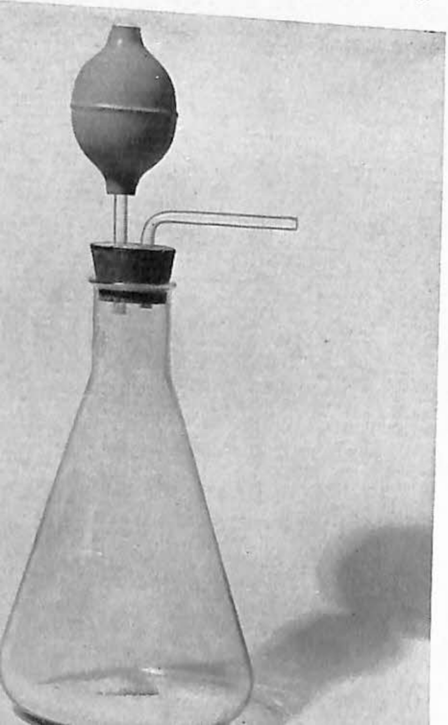


This simple experiment gives you proof of what you probably believed to be true, or it may have given you further proof of what you knew to be true from your former experience with fires. It also helps you to understand some of the things that you have at home. *How do you make a smouldering fire burst into flames? What do you regulate in order to make sure that a fire or stove burns slowly and thus stays alight longer?*

OXYGEN AND FIRES

Air is a mixture of a number of gases, one of which is oxygen. You can make an experiment to see whether things burn better in pure oxygen or in air (of which about one-fifth only is oxygen). Figure 20 shows an apparatus for making oxygen. Place a splinter which is just glowing in ordinary air, close to the tube leading out of the flask. What happens?

FIGURE 20. Making oxygen. The flask contains a few teaspoonfuls of sodium peroxide and the bulb contains water. A few drops of water from the bulb will cause oxygen to be given off. Add water, with great care, a little at a time as needed.



How to extinguish fires. All the fires you meet in everyday life need oxygen to keep them burning and this oxygen comes from the air. If you want to make something burn better, you increase the supply of air. If you want to put out a fire, you must find some way of keeping air away from the fire.

In Figure 19 a tumbler was used to smother the small fire of the burning candle by shutting out the supply of air. If somebody's clothes catch on fire the quickest way of putting them out is smartly to wrap the person in a rug or mat or thick woollen blanket.

Water often provides the best method of extinguishing fires. It acts in several ways; partly it cools the burning object and other things near it, below the temperature at which they will catch fire; partly the water absorbs heat from the fire in being converted into steam; and partly the steam which is produced acts as a blanket to keep oxygen away. But if a pool of oil on a garage floor catches alight, a jet of water will merely scatter little spurts of burning oil all over the place. So garages have buckets of sand with which to smother such fires.

Can you see why water is of little use as a fire extinguisher when a burning substance, such as petrol, is *lighter* than water and therefore floats on its surface? Fortunately some liquids when heated turn rapidly into gases that are much heavier than steam or air. Such liquids are used in the handy fire extinguishers kept in cars and motor buses or on the walls of garages. We do not squirt the liquids into the hottest part of the fire because there the flames might carry some of the gas away. So we squirt the liquid around the bottom of the fire and/or over the top of a burning tank or pan.

The liquids used may successfully put out the fire but we must be on our guard against two dangers in using them. We have seen how water may spread a petrol fire instead of extinguishing it. It is also necessary to be careful in using water on electrical apparatus or wiring or plugs, for the water conducts electricity and can give dangerous shocks. The liquids used in the handy fire extinguishers for cars and garages do not conduct electricity easily and so are free from this risk, but the liquid most commonly used does give off poisonous fumes. So if you use such a fire extinguisher inside a building, get out into the open air yourself and ventilate the building thoroughly as soon as the fire is out.

SOME THINGS YOU MAY CARE TO DO

1. Here is an interesting and easy experiment that you can perform at home in a few minutes. *Put out a fire by using carbon dioxide gas.*

Place two teaspoonfuls of baking soda in a tumbler and then add two tablespoonfuls of vinegar to cause the soda to give off carbon dioxide. Lower a lighted match into the tumbler. Do not drop the match into the liquid because it is the *gas* you wish to test.

2. Using what you have learned, write out the following statements, but make each of them true by using only one of the words or phrases in italics.

(i) To make the fire in a stove burn faster, the draught should be (*a*) *increased*, (*b*) *reduced*, (*c*) *stopped altogether*.

(ii) Small oil fires should be extinguished with (*a*) *water*, (*b*) *blankets*, (*c*) *sand*.

3. Ask your teacher if he can arrange for a fire prevention officer from the local Fire Service to talk to your class about ways of keeping oxygen from fires. He may even stage a demonstration for you and arrange a class visit to the Fire Station.

4. Paste into an exercise book a collection of advertisements for different kinds of fire extinguisher and against each one write an explanation of how it acts.

5. Perhaps some members of your class can prepare talks for the others on (*a*) carbon dioxide for extinguishing fire, (*b*) foam blanketing for big petrol fires.

Question 2. **Do Fires Take Anything from or Add Anything to the Air?**

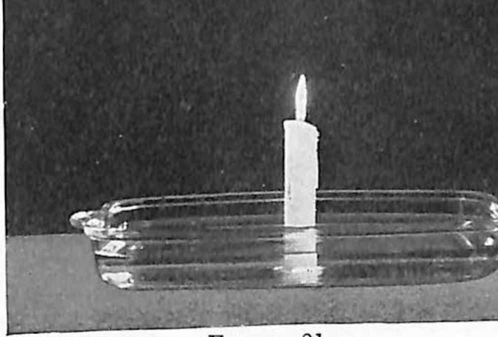


FIGURE 21.

Because oxygen causes things to burn, you might expect that fires use the oxygen of the air. You can test this idea in a very few minutes by using the apparatus shown in Figure 21. First fasten the candle to the bottom of the dish with a little of the melted wax. Now add some water, light the candle and cover it with a jar. Results are shown in Figure 22.

Why did the candle burn at first?

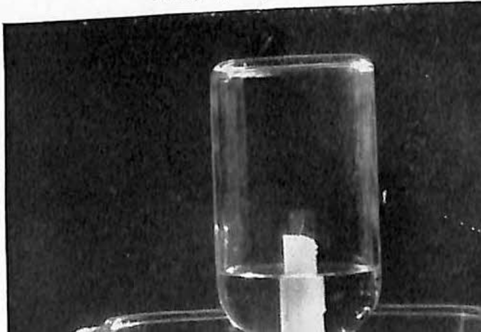
Did it use all the air in the jar?

Why did it go out?

Do fires add anything to the air? When a candle burns it gradually disappears. Have you wondered what becomes of the wax? Chemists tell us that when the candle burns the oxygen of the air turns the wax into moisture and carbon dioxide. Even though the carbon dioxide is colourless, you can prove that it is formed if you study it the way a chemist would. He has found that it will turn lime water milky. He calls this a test for carbon dioxide. It is quite an easy and interesting test.

To find out whether a candle flame gives off carbon dioxide you need only send some of the air from just above it into lime water. This experiment must be done as a scientist would do it if you want to be sure of your answer.

FIGURE 22. Why did the water rise in the jar?
Photographs by M. S. Smith



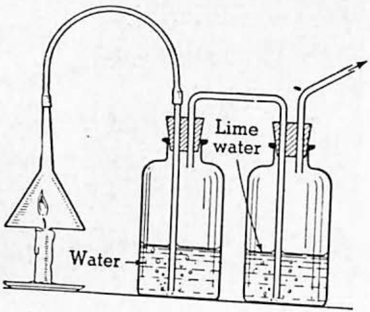


FIGURE 23. A candle is used because it is safe and handy, but a splinter of wood may be used.

One good way is shown in Figure 23. You see that the air is not drawn right into the lime water. It is made to pass through some ordinary water first. This is done to make sure that if the lime water turns milky, it was *not* due to smoke from the flame or from dust in the air. If dust or smoke is present, the water in the bottle will catch it. The bubbles that you see when you first suck on the tube come from the ordinary air that was in the bottles. But after you have drawn this out, you will begin to get air that was once over the flame. You can then see how this differs from ordinary air.

Does it turn the lime water milky?

Does a burning candle add carbon dioxide to the air?

TWO GASES

Carbon dioxide gas is harmless. Paraffin lamps, oil stoves, and gas stoves put much carbon dioxide into the air of rooms, but it does no harm. You remember this is the same kind of gas you get in your mineral waters. You will see later that it is really very useful. If an oil stove is burned for some time in a small tightly-closed room, a bathroom for example, it may take so much oxygen out of the air that a person could not get enough to breathe. This, however, does not mean that the carbon dioxide is dangerous, but only that needed oxygen is absent.

Carbon monoxide is dangerous. Some fires give off another gas besides carbon dioxide. This is the very poisonous carbon monoxide. When petrol burns in the engine of a motor-car, carbon monoxide often comes out of the exhaust pipe. That is why people are warned not to run their engines in a garage with the doors closed.

What is now your answer to the problem: *How is air related to fire*?

SOME THINGS YOU MAY CARE TO DO

1. Collect some of the water that is formed when a candle burns. It is best to use a rather large glass jar. A quart jar is too small. The candle should be placed as shown in Figure 24. The jar may be kept cold by wrapping it with cloths wet with ice water. Be sure the cloths are not so wet that water from them will flow down the outside of the jar. The jar may be held in the position shown in Figure 24 by hanging it from a support by means of adhesive tape. You may find an easier way to keep your jar in place. (In the next Unit you will learn why the water formed by the burning candle tastes "flat" like rainwater.)

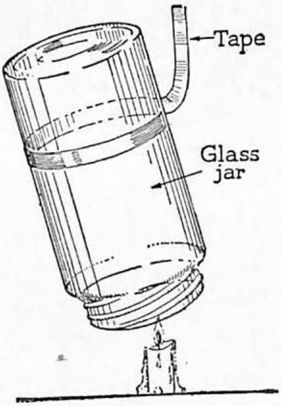


FIGURE 24. Do not allow the flame to touch the glass jar. Avoid draughts as much as you possibly can.

2. Try to answer two questions on the scientific method:

a. In the last experiment why were you not advised to use a second jar without a candle, as a control?

b. If a control were needed to make sure of your results, how could you use the glass jar for a control before using it in the experiment?

After you have reasoned out the answers, discuss them with your teacher.

Problem C: **CAN LIVING THINGS DO WITHOUT AIR?**

Now that you know something about the gases in the air, you are ready to learn how both plants and animals make good use of the oxygen and carbon dioxide in the air. Boys and girls sometimes try to see how long they can hold their breath. The winner of one such contest, who held his breath less than three minutes, had to be sent to a hospital. Anyone will die in a short time if he cannot get air into his lungs. But because you breathe all the time, you probably do not wonder how you do it.

Problem C: Can Living Things do without Air?

Question 1. **What makes Air go into the Lungs?**

Before studying your own lungs, it is best to try an experiment with a model. A good one is shown in Figures 25–27. The balloons must be fastened so tightly to the glass tubes that air will not leak out when they are blown up. If the stopper fits tightly and the rubber sheet is fastened so that air cannot leak, the balloons will be in an airtight cavity. The marble is used to make a good handle for moving the rubber sheet.

If every joint is tight, the balloons will be blown up when you pull down on the marble, and they will collapse when you let the rubber snap back. You can find out whether the air moves into or out of the glass

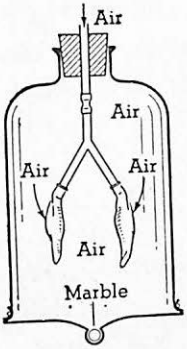


FIGURE 25. Air can enter the balloons, but it cannot get into the glass jar.

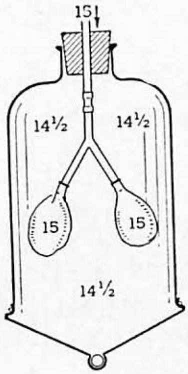


FIGURE 26. When you pull the marble, the balloons blow up.

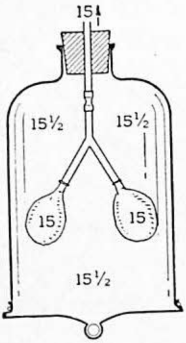


FIGURE 27. When you let go, the balloons collapse and pressure in the jar soon goes back to 15 pounds.

tube by holding the flame of a lighted match close to the end of the tube.

Does the flame ever enter the tube? If so, when?

To understand why the balloons act as they do when the rubber is moved, you need only consider what you learned about air pressure. When the model is not in use, there is ordinary air inside the jar and inside the balloons. You remember that the air pressure is about fifteen pounds on each square inch, and that it pushes equally in all directions. Because the pressure on the thin rubber of the balloons is just the same inside and outside, the balloons behave as if there were no pressure at all and hang limply from the glass tubes.

But when the sheet of rubber is pulled down, there is more room in the jar. The air in the jar is thus less crowded, and its pressure becomes less than fifteen pounds per square inch. The pressure in the balloons and in the glass tubes and outside is still fifteen pounds per square inch. The push of the air inside the jar on the balloons therefore does not balance the pressure inside the balloons. The stronger push wins, and the balloons are blown up as you saw them in the model. Figure 26 will help you to understand the reasons. *Why does the air go out of the balloons?*

When the balloons swell up, they take up much of the room inside the jar. Thus, when the rubber snaps back there is less space for the air than there was when they were limp. As the rubber moves back it crowds the air all around the balloons. Because the air is crowded it pushes harder than it did at first. Its pressure is thus *greater* than fifteen pounds per square inch. The greater push again wins, and air is squeezed out of the balloons. (See Figure 27.)

SOMETHING YOU MAY CARE TO DO

Make a model of the lungs in the chimney of an oil-lamp. Try to get a large chimney with bulging sides. If you have a cork for a stopper, you will need to seal it with wax to make it tight. Use small balloons, and blow them up a few times before putting them into the model. This is to make them stretch more easily. If your teacher cannot provide you with a Y tube, you can make one out of three short pieces of glass tubing and sealing wax. If the tubes should become stopped while you are fastening them together, you can clear them by inserting a hot wire or knitting needle. For the rubber sheet you can use a piece of toy balloon. It can be made airtight by holding it in place with several rubber bands. A bead or pebble will serve in place of the marble in the large model. If your model fails to work well, hunt for a leak.

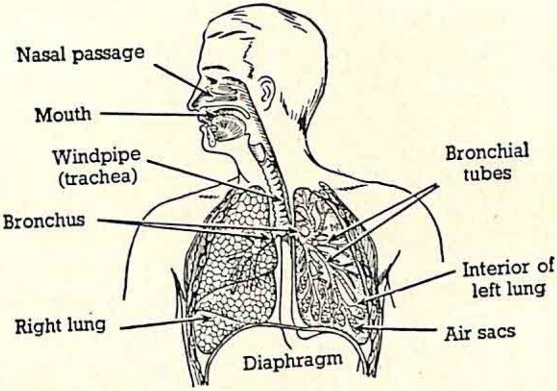


FIGURE 28. How does air reach the lungs ? How does it leave the lungs ?

Problem C: Can Living Things do without Air ?

Question 2. **How do you Breathe ?**

Now that you know how air can be made to move into and out of balloons, you are ready to study how you breathe. Figure 28 shows how the lungs are connected with the windpipe. Instead of being a single sac, like a balloon, each lung is made up of many small air spaces. A series of tubes connects these air spaces with the windpipe. In your body a wall of flesh takes the place of the glass jar used in the model. Instead of the rubber sheet of the model, there is a sheet of muscles called the *diaphragm* across the bottom of the chest cavity. This makes the cavity airtight.

Breathing. You can see from the drawing that the diaphragm is not flat, as was the sheet of rubber, but is curved. It is shaped something like a saucer turned upside down. When the muscles of the diaphragm contract, it becomes somewhat flatter and is drawn down. This motion of the diaphragm will cause some

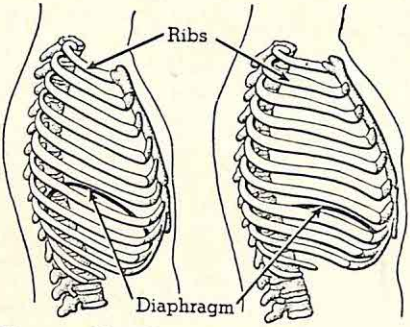


FIGURE 29. Raising the ribs expands the chest.

air to flow into the lungs, but the motion is not nearly great enough to give you all the air you need. How, then, do you get sufficient air?

When you take a deep breath, you can feel the ribs being drawn up and you know that the chest becomes larger. This movement of the ribs, enlarging the chest cavity, helps to reduce the pressure of air in it. More air will then be pushed in from outside, because there the air pressure is greater. You must remember that it is not the air that you inhale that expands the chest, but the expansion of the chest that allows the air to enter the lungs. Figure 29 shows how raising the ribs increases the size of the lung cavity.

When the ribs drop back, the air in the lungs is partly squeezed out. This action is usually quite gentle. But when you sneeze or cough, the muscles act very suddenly, and air is forced out in a puff.

Breathing may be difficult. You breathe so easily that you scarcely know it except when you are running or working hard. Those who fly, however, sometimes find it hard to breathe. Because the air high above the earth is thin, there is less oxygen in a quart of it than there is in a quart of air near the ground. Thus a person gets less oxygen than usual every time he inhales. To get the needed amount he breathes deeper and harder. Sometimes this gives him enough oxygen, but if he flies high enough there may be a lack of oxygen in spite of anything he may do. Airmen who must go up to great heights carry tanks of oxygen which they can use when the air gets too thin for safety. The cabins of some aeroplanes are sealed so that oxygen can be added to the air in them.

Persons who are very ill cannot always get from ordinary air enough oxygen to keep them alive. They are then sometimes placed in an oxygen tent. Oxygen which has been compressed into big iron bottles is kept on hand ready for use. By opening a valve, which works like a water tap, as much or as little oxygen as may be needed can be placed in the tent.

SOME THINGS YOU MAY CARE TO DO

1. Using a tape measure, or string and a long ruler, measure your chest expansion when you take a deep breath.

2. Make a model of cardboard to show how lifting the ribs expands the chest. No directions will be given, but you can get a hint from Figure 29.

3. Using fruit jars, measure how much air you exhale in an ordinary breath, and when you take a deep breath. First fill the jars with water and stand them bottom up in a pan about half full of water. Use a piece of rubber hose to get the air from the mouth into the jars.

Problem C: Can Living Things do without Air?

Question 3. **How does Exhaled Air differ from Ordinary Air?**

You found that fires add carbon dioxide and moisture to the air.

Everyone knows that water will collect on a cold window-pane when you breathe upon it. You need no further experiment to show that breathing adds water to the air. However, you breathe out far more water in a day than you may think.

Is it not possible that some carbon dioxide is also given off when you breathe ? Since you know the test for carbon dioxide, all you need to do to answer this question is to blow into a glass of lime water. Use a deep breath to make sure that the air comes from the lungs and is not just some ordinary air from the mouth and throat.

Did the lime water turn at all milky with the first breath ?
Did it turn more milky with the second breath ?
What substances are added to the air when you breathe ?

It is not so easy to find out what breathing takes from air. Scientists can show that the blood in the lungs removes oxygen from air. But does all the oxygen that enters your lungs pass into your blood ? This is easy to answer.

First fill a jar with exhaled air as shown in Figure 30. Before taking the jar from the water, cover it with a piece of glass to keep the exhaled air from mixing with ordinary air. Wrap a piece of wire around a small candle and light it. After it is well lighted, move the glass a little to one side and quickly lower the candle into the jar. Then close the jar again. If all the oxygen has been taken from the air, the candle will go out almost at once. But you will probably find that the candle will burn for a short time and then go out, just as it did when you placed it in ordinary air in a previous lesson.

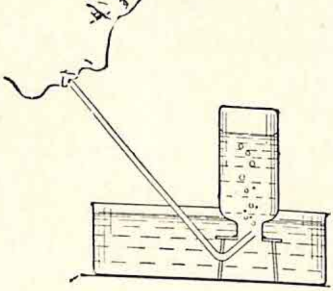


FIGURE 30. Why is it unscientific to send the very first part of the breath into the jar ?

Do you see why a person who gets trapped in a safe does not die at once? Why is it necessary to get the safe open within a few hours to save his life?

ANIMALS NEED OXYGEN

So much for the breathing of people. Do animals breathe, too? Some animals do not have lungs, but can get their oxygen in other ways. Later you will find out how such things as fish, flies, and grasshoppers obtain air. All animals must get oxygen in one way or another.

Do you see now how fires act like animals, including people? Both use the oxygen of the air, and both add water and carbon dioxide to the air.

Scientists now know that much of the food we eat disappears, and that as a consequence carbon dioxide and water are given off. The blood brings these substances to our lungs, and we add them to the air when we exhale. Heat is given off, too. The disappearance of the food within the body is so nearly like the disappearance of things when they burn that we may say we burn food to keep us warm. There is one difference—there are no flames inside the body when materials that come from foods are changed into carbon dioxide and water. Scientists usually do not say the food is burned in the body, but that it is *oxidized*.

FIGURE 31.

SOMETHING YOU MAY CARE TO DO

Burn some food to show that it gives off carbon dioxide and water. *Hint:* Sugar may be burned if placed on an ordinary marshmallow which is then ignited. Collect a bottle of the gas which is coming from the flame and test with lime water.

Problem C: Can Living Things do without Air?

Question 4. **Do Plants need Air?**

Since ancient times farmers have always ploughed their fields before they planted their seeds. They have learned that unless they do so they do not get good crops. The farmer of today knows that if his plants are to make a good growth he must keep the ground porous so that air may get into it. Just how the plants make use of the air in the soil must be left to other lessons. For the present it is enough to know that air is needed. Perhaps you wonder if you can show this by an experiment at home. Yes, if you are not in a hurry you can show that sprouting seeds need air. You must remember that scientists may have to wait months and sometimes years for some of their answers. You can get your answer to this question in about a week.

Fill two glass bottles about three-fourths full of cotton-wool. Do not pack it down. Sprinkle the cotton-wool with water until it is quite wet. Then place a few beans, which have been soaked overnight in water, on the cotton close to the walls of the glass as shown in Figure 32. Partly cover the beans with the damp cotton-wool.

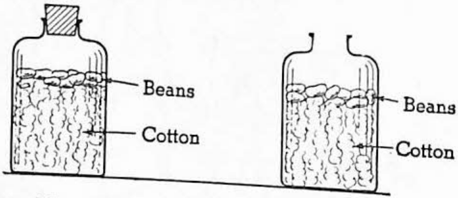


FIGURE 32. Why should the beans be placed close to the sides of the bottles?

Seal one bottle airtight, waxing the cork. If you use a cardboard cap, coat it with paraffin to make it tight. Place the bottles in a warm spot where they will not be disturbed and keep the cotton-wool in the open bottle damp. After a few days you can tell whether the seeds grow equally well in both bottles. In thinking about the results, remember that there is some air in the closed bottle.

Scientists have discovered that the green leaves of plants also make use of air. They use air in making stems, leaves, flowers, and seeds. Such foods as sugar, maize and rice are made almost entirely from air and water. You can conclude, then, that plants need air.

In which bottle is the growth better ?

How have the four problem-questions helped you to solve the problem : Can living things do without air ?

SOMETHING YOU MAY CARE TO DO

Show that sprouting beans give off carbon dioxide. Arrange the apparatus as shown in Figure 33. Use about thirty beans and place them upon wet blotting paper until they are sprouted. Next, put them into the bottle and let them continue to sprout for two or three days. Then insert the stopper, wait two or three hours, and force the air slowly through the lime water.

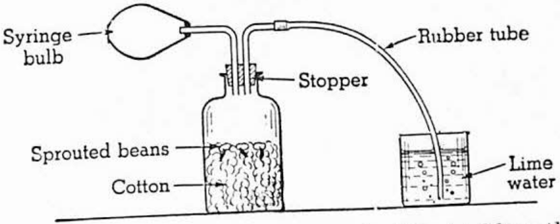


FIGURE 33. Why would it be unscientific to blow the air out of the bottle rather than to use the bulb ?

Why is an empty bottle not needed as a control in this experiment ?

Problem D: **COULD WE HEAR IF THERE WERE NO AIR?**

Man and animals use air in other ways than to help sustain life. One way in which they use it concerns sound. In the far-off Antarctic, hundreds of miles from a living soul, the ice is cracking up and waves are dashing upon the icy shores of the sea. Is there any sound there ? Some may say " No," because there are no ears to hear it. Others may say " Yes," because there are penguins there to hear it. Still others will say, " There is sound there anyway, whether or not there may be ears to hear it."

Before you can answer this question for yourself, you will need to know what we mean by the word " sound."

Problem D: Could we Hear if there were no Air ?

Question I. **What Causes Sound ?**

Stretch a rubber band between your two hands and have a second person pull it to one side and then release it suddenly. As long as the stretched band is still, no sound comes from it ; but when it is moving, it will make a noise. As soon as it stops moving, the sound will cease.

What evidence was there that the band was moving while giving off sound ?

Sometimes boys like to fix rubber bands from the handlebars of their bicycles to the front forks. When they cycle the rubber makes a whirring sound. Does the note change with the speed of the bicycle ? Does the tightness of the rubber affect the note ? Perhaps you, and some of your friends, will experiment. If so, try to explain what you discover.

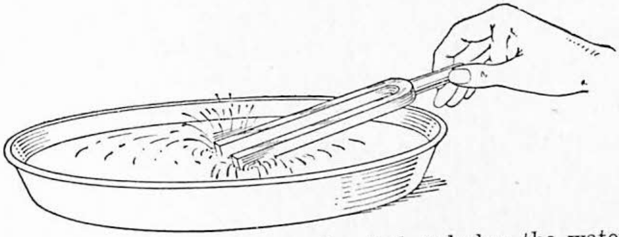


FIGURE 34. A sounding tuning fork splashes the water.

Figure 34 shows what occurs when a tuning fork which is giving off a sound is dipped in water. The tuning fork is moving so rapidly that you cannot see the motion. Figure 35 shows that the fork is moving back and forth like the rubber band. When anything moves back and forth in this way, it is said to be *vibrating*.

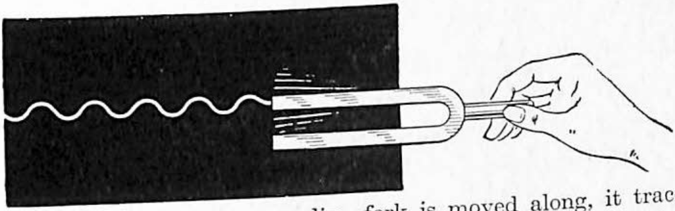


FIGURE 35. When the sounding fork is moved along, it traces a wavy line on smoked glass.

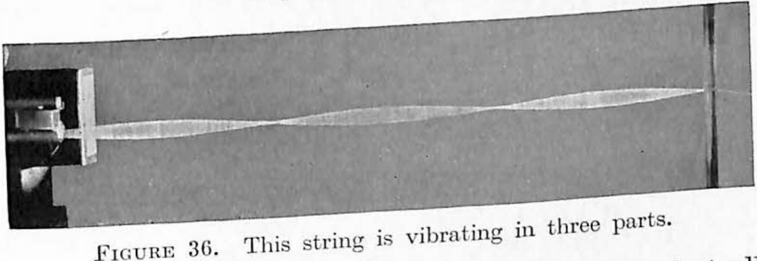


FIGURE 36. This string is vibrating in three parts.

Almost every object can be made to vibrate, but all do not do so in the same way. A string of a harp may vibrate as shown in Figure 36. A drumhead may act in some other strange manner when giving off sound, but you can be sure that if a sound is coming from a whistle, or a creaky door, or the wind, or anything whatsoever, something is vibrating.

In a harmonica it is the small metal strips or reeds. Hammers pound the strings of a piano, and a bow starts the vibrations of violin strings. The crash you hear when a drinking glass falls and breaks comes from the vibrations of the pieces of glass and the floor. If you blow across the mouth of a bottle you will hear the sound made by the vibration of air in the bottle. Band music comes chiefly from the vibrating air inside the horns. What is moving to produce the buzz of a mosquito ?

Not all vibrating bodies produce sound. You know that objects hanging from a support may swing back and forth without making a noise, and that jelly quivers noiselessly. You will see later that these move too slowly to be heard. The human ear does not hear a sound if an object vibrates either too slowly or too rapidly. However, it is possible that some animals may hear sounds which we cannot detect.

A musician may think of sound as the effect produced upon the ear, but a scientist thinks of it as the kind of vibration that *can produce* an effect upon the ear. Thus, in science we say that there *is* sound in the Antarctic, whether it is heard or not.

SOMETHING YOU MAY CARE TO DO

Show that the head of a banjo or the wood of a guitar vibrates. To do this, place a few grains of puffed rice or puffed wheat on the instrument. Then pluck the largest string vigorously and watch the grains closely. See whether the vibrations are more noticeable in one place than in another.

If you have a drum, try the rice on it, but do not strike the drumhead too hard at first.

Question 2. **Is Air needed to Carry the Motion of a Sounding Body to the Ear?**

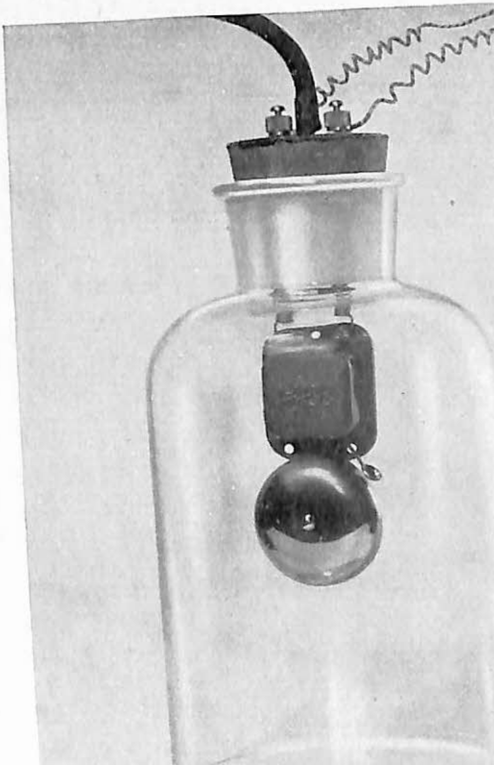
A good way to begin your study of this question is to listen to an electric bell placed in a bottle as shown in Figure 37.

Before connecting the air pump to the bottle, make sure that it works well. Sometimes a drop of oil will improve it. Because the pump takes out only a little air with each stroke, you must not expect startling results just at first. If the sound of the bell does not become weaker and weaker as you pump, look for a leak. After the sound has become very faint, allow air to enter the bottle and notice the change in loudness.

It is difficult to make the sound disappear entirely because some may be carried to the outside by the wires, and there will always be some air left in the bottle. However, complete silence is not needed to show that air carries sound to the ear. It is enough to know that the sound grows weaker and weaker as the air is taken from the bottle.

Why do you not expect the sound to cease suddenly?

FIGURE 37.



Sound will travel through solid substances. Ordinarily it is air that carries sound to the ear, but you can show that other substances will also carry sound. Place your ear on top of your desk and then tap or scratch the top with your fingernail. Or place one end of a long window pole against the lobe of your ear and ask a classmate to tap or scratch the other end. These sounds that cannot be heard through the air of the room may be distinctly heard through the pole.

Most solids will carry sound. Such things as glass, plaster and stone carry it very well, while sawdust, sand and cloth do not. The steel rails of a railway track carry sound so well that a dog that happens to be near them may hear a train coming before the train can either be seen or heard by a person standing beside the tracks.

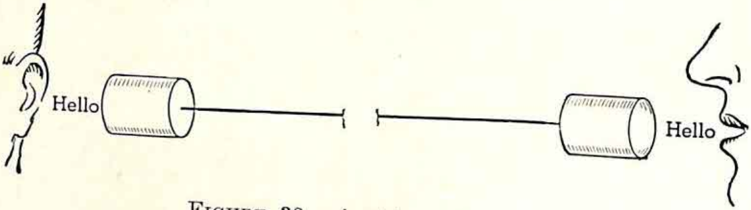


FIGURE 38. A string telephone.

A string telephone can be used to show that even a cord can carry sound. Such telephones can be made from cylindrical cardboard boxes or metal tins. For best results make only a small hole in the centre of the bottoms of the tins and draw the string tight while using it. Figure 38 shows the tins close together, but they may be placed in different rooms. It is best not to wrap the cord around a support; simply allow the cord to rest upon it.

You probably can hear better through the air than through the string, but you have proved that a cord can carry a sound. Before electric telephones were in use, string telephones, using wire instead of string and large tin pans instead of small tins, were sometimes used between places a quarter of a mile or so apart. To attract attention one of the pans was pounded. Of course a speaker had to talk in a very loud voice.

Water will carry sound. You may have found while swimming that water will carry sounds made under the surface. If the wind is blowing hard it is useless to fish near a lake shore covered with loose stones the size of an egg, because the sounds produced when the waves pound the stones together frighten the fish away.

Because so many things about us are moving over or against each other, thus causing vibrations, the air is usually full of sounds. Some are faint and some are loud. Because sounds become fainter as you get farther away from a sounding body, most sounds cannot be heard even a quarter of a mile. You may have seen lightning so far away that you could not hear the thunder. Glider pilots have said that when they are high in the air so few sounds reach them that the almost complete silence is one of the things they will never forget.

What two things have you proved are necessary to produce sound?

SOMETHING YOU MAY CARE TO DO

You know that thunder sometimes shakes windows. See if you can use sound to make a candle flame flicker or perhaps blow it out. The apparatus is shown in Figure 39.

The small megaphone may be made of cardboard or paper. The tube may be made of almost any material,

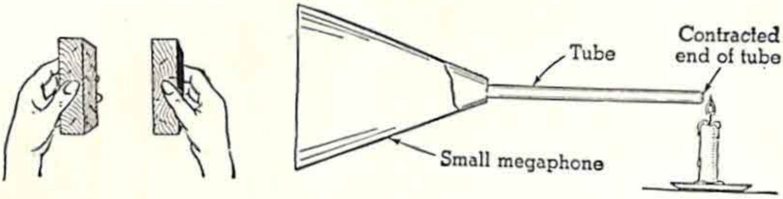


Figure 39.

but it should not be more than one inch in diameter and should be even smaller at the end near the candle. A loud sharp sound can be made by striking two blocks of wood together near the megaphone.

A scientist would make sure that it was the sound and not the draught through the tube that acted upon the flame. You can do this by placing a little smoke in the tube. How does the smoke help you to be sure of your facts ?

REVIEW QUESTIONS

1. What proof can you give that air takes up room ?
2. What is the weight of a cubic foot of air ?
3. What is the cause of air pressure ?
4. Give two uses of air pressure.
5. Why may sand be used to put out a fire ?
6. What substances do fires add to the air ?
7. Why does the air enter the lungs when we inhale ?
8. How does exhaled air differ from ordinary air ?
9. What is meant by the statement that a sounding body is a vibrating body ?
10. How does air help us to hear ?

A TEST OF YOUR SKILL IN THE USE OF THE METHOD OF A SCIENTIST

(*Read the following description at least twice before you try to answer the question which follows it.*)

Two boys tried to see if they could show that exhaled air contains less oxygen than ordinary air.

The first boy used one bottle and one candle. He lighted a new candle and lowered it properly into the bottle full of exhaled air and left it until it went out. He timed it to see how many seconds it burned. He then filled the same bottle with fresh air, relighted the candle, and repeated the experiment, using the same watch.

Result: He found that the candle burned for a *longer* time in the bottle of *exhaled* air.

The other boy had two candles and two bottles of the same size. He used a candle that had been burned before in the jar of ordinary air and a new candle of the same size in the bottle of exhaled air.

Result: The candle in the exhaled air burned for a *longer* time than the one in ordinary air.

Both these results seem to show that chemists may be wrong when they say exhaled air contains less oxygen than ordinary air. Their teacher, however, told the boys that they had not correctly followed the ways of a scientist.

What did the boys do that a scientist would not have done if he had been doing these experiments?

TRUE OR FALSE?

Some of the following statements are true, others are false. On a sheet of paper write numbers from 1 to 15 and against each number put the word *True* or *False*.

1. Air is not a substance because it cannot be seen.
2. When water is poured into a tumbler, air leaves the tumbler.
3. Air weighs about a pound per cubic foot.
4. An ordinary wind exerts no force upon objects in its path.
5. All winds are harmful to man.
6. Still air exerts a pressure upon objects.
7. Fires remove oxygen from the air.
8. A wood fire adds carbon dioxide to the air.
9. A wood fire adds water to the air.
10. The breathing of animals does not add water to the air.
11. While inhaling, the air pressure inside the air spaces of the lungs is greater than that of the air outside the body.
12. Trees need air in order to grow.
13. An object may vibrate too slowly to produce sound.
14. Sound will travel in air but not through water.
15. Sound will not travel through a solid substance.

CAN YOU RECOGNIZE THE PARTS OF AN EXPERIMENT?

When a scientist does an experiment, he has to be orderly in his work and in his thinking. This means four things:

(1) He has to keep clearly in mind the QUESTION he is trying to answer.

(2) He must keep an exact record of his ACTIONS.

(3) He must keep an exact record of what he OBSERVES.

(4) He has to decide what his observations mean. That is, he has to draw CONCLUSIONS from what he observes.

Here is a group of statements describing an experiment. Each sentence in the group refers to one of the four things a scientist must do when he experiments.

Question 1. A boy wanted to find out whether the oxygen in air really helped things burn.
Action 2. He got a bottle of air, a bottle of pure oxygen, and a bottle of air from which the oxygen had been removed.
Action 3. He dropped a burning piece of paper in each bottle.
Observation 4. He saw that the paper in the bottle of oxygen burned much more rapidly than the paper in the bottle of air.
Observation 5. He noticed that the flame went out in the bottle of air from which oxygen had been removed.
Conclusion 6. He decided that he had evidence to show that oxygen in air helped paper burn.

Copy each of the following experiments, putting in front of each number the name of the part of the experiment in the same way as has been done above.

FIRST EXPERIMENT

1. A girl read that all living things need oxygen, and wondered how fish got the oxygen they needed.
2. She carefully examined the aquarium in the science room.
3. She noticed that it contained plants.

4. She noticed that when the sun shone on the aquarium, bubbles formed on the leaves of the plants.
5. Next she put a glass of water in the sunlight.
6. She saw bubbles on the sides of the glass.
7. She guessed that the bubbles were air bubbles.
8. She decided that fish probably got air from water.

SECOND EXPERIMENT

1. Two boys wanted to see whether exhaled air contained more moisture than ordinary air.
2. Each boy blew against a window-pane.
3. They noticed that moisture appeared on the glass.
4. They wondered how they could blow ordinary air against the window-pane.
5. One of the boys got his bicycle-pump.
6. He pumped air against the pane.
7. Neither boy noticed any moisture on the pane.
8. They decided that exhaled air had more moisture in it than ordinary air.

THIRD EXPERIMENT

Tie two teaspoons together at the end of a length of string in such a way that when you move the string the spoons knock together and jingle. Now fill the bath with water and lower the spoons into the water and make them jingle. Ask someone to put his ear against the outside of the bath and to listen. Then let him jingle the spoons while you listen.

Do you hear the jingling better when you are holding the string or with your ear against the bath ? Explain your answer. Why must you take care not to let the spoons touch the metal of the bath or come above the water ?

CAN YOU SELECT THE BEST CONCLUSION ?

Drawing conclusions may be the hardest part of an experiment. A scientist wants to draw all the conclusions he can from the work he has done. He also wants to be perfectly sure that what he has done gives him the right to make these conclusions.

A student placed some bean seeds in each of two bottles containing soil. One bottle was closed with a stopper, while the other was kept open. The temperature and amount of moisture in the bottles remained the same. Only the beans in the open bottle continued to grow.

Does this show that (*a*) bean seeds need sunlight for growth, *or* (*b*) beans need some part of air to sprout, *or* (*c*) bean seeds need warmth to sprout, *or* (*d*) beans should be grown in a bottle ?

ANSWER : (*b*).

Now select the best conclusion from each of the following sets of facts :

1. Whenever carbon is burned in oxygen, a gas called carbon dioxide is formed. A diamond was burned in oxygen and all of it combined with the oxygen to form carbon dioxide. Does this show that (*a*) diamonds are made of carbon, *or* (*b*) diamonds can burn in air, *or* (*c*) the manufacture of carbon dioxide is an expensive process, *or* (*d*) diamonds contain some carbon ?

2. Automatic fire extinguishing is provided in many buildings by a system of fine jets of water which spray like a lawn hose if fire breaks out. Is this arrangement made because (*a*) a little water puts out a fire better than a lot, (*b*) the spray and the steam will stop oxygen getting to the fire, (*c*) the jets will wet everything in the room, (*d*) the arrangement will economize water, (*e*) furniture will not be damaged by too much water ?

3. John brought to class a whistle which nobody could hear when he blew it. John said that his dog always ran to him when he blew on it. Does this show that (*a*) John was jumping to conclusions, as it was just chance that his dog ran to him, *or* (*b*) perhaps dogs can hear some sounds which human beings cannot hear, *or* (*c*) John was stretching the facts to make a good story, *or* (*d*) John blew his whistle too softly for other boys to hear ?

SCIENCE ON THE MARCH

The Air and You
Water and Life
The Weather and the Earth
Life and Food
Health
Energy and Engines
Hearing and Seeing
Electric Currents
Magnets and Electric Power
Earth and Universe
Heating and Cooling
Birth and Growth
Metals and Man

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